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Inferior results of salvage arthrodesis after failed ankle replacement compared to primary arthrodesis

Rahm, Stefan ; Klammer, Georg ; Benninger, Emanuel ; Gerber, Fabienne ; Farshad, Mazda ; Espinosa, Norman

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DOI: https://doi.org/10.1177/1071100714559272

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ZORA URL: https://doi.org/10.5167/uzh-104597
Journal Article
Accepted Version

Originally published at:
Rahm, Stefan; Klammer, Georg; Benninger, Emanuel; Gerber, Fabienne; Farshad, Mazda; Espinosa, Norman (2015). Inferior results of salvage arthrodesis after failed ankle replacement compared to primary arthrodesis. Foot and Ankle International, 36(4):349-359.
DOI: https://doi.org/10.1177/1071100714559272

Foot & Ankle International

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Foot Ankle Int published online 6 November 2014
DOI: 10.1177/1071100714559272

The online version of this article can be found at:
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Inferior Results of Salvage Arthrodesis After Failed Ankle Replacement Compared to Primary Arthrodesis

Stefan Rahm, MD[1], Georg Klammer, MD[1], Emanuel Benninger, MD[1], Fabienne Gerber[1], Mazda Farshad, MD, MPH[1], and Norman Espinosa, MD[1]

Abstract

Background: Up to now, there has been no evidence that salvage arthrodesis would perform inferior when compared with primary ankle arthrodesis. The purpose of this study was to compare their clinical and radiographic results.

Methods: A retrospective analysis was performed using 2 validated scores and assessment of radiographic union by comparing 23 patients who underwent salvage ankle arthrodesis (group SA = salvage arthrodesis) after failed total ankle replacement with 23 matched patients who received primary ankle arthrodesis (group PA = primary arthrodesis). The mean follow-up period was 38 (range 16-92) months in group SA and 56 (23-94) months in group PA.

Results: Complete union was achieved in 17 patients (74%) after a mean time of 50 (13- 114) weeks in group SA and in 16 patients (70%) after a mean time of 23 (10-115) weeks in group PA. The SF-36 score averaged 48 points (7-80) in SA and 66 points (14-94; *P* = .006) in group PA. In group SA the mean FFI was 57% (22-82) for pain and 71% (44-98) for function. In group PA significantly better results for pain with 34% (0-88; *P* = .002) and function with 48% (1-92; *P* = .002) were found.

Conclusion: Salvage arthrodesis led to impaired life quality and reduced function combined with significantly higher pain when compared with primary ankle arthrodesis. These findings can be used to counsel our patients preoperatively.

Level of Evidence: Level III, retrospective case series.

Keywords: ankle, arthrodesis, salvage, failed total ankle replacement, TAR

There is an ongoing debate whether to choose total ankle replacement (TAR) or ankle arthrodesis in the surgical treatment of symptomatic end-stage ankle osteoarthritis.[2,6,7,10,17,21,24,34,37] While contemporary TAR designs, reveal superior and more reliable overall clinical outcomes and low revision rates,[2,11,13,21,27,36] the long-term results are still not yet predictable and do not match those in total knee- and total hip arthroplasty.[1,3,5,17,19,25,32]

With an increasing number of patients undergoing TAR the number of patients who will need a revision operation will rise. Neglected misalignment, medial or lateral gutter impingement, component loosening, polyethylene displacement and progressive wear, infection and persistent pain are potential factors that ultimately led to revision operation.[4,30,38] It sounds logical that—whenever possible—the implant should be salvaged and retained. This can be achieved by adding surgeries (eg, osteotomies, ligament reconstructions)[2,6,7,10,12,21,24,35,37] or simple component exchange.[2,9,11,18,20,21,23,27,29,31,36,39] However, there will always be patients who are not amenable to this kind of treatment and conversion to an arthrodesis can be considered.

While several studies investigated the radiographic and clinical outcomes after primary ankle arthrodesis, there is a paucity of reports available in the literature that deal with salvage arthrodesis after failed TAR.[2,3,6-8,10,17,21,24,34,37] To the best of our knowledge there has been no comparative analysis performed to assess salvage arthrodesis after failed TAR and primary ankle arthrodesis. The current study was undertaken to investigate the outcome of salvage ankle or hindfoot arthrodesis after failed TAR and to compare it with a matched control group of patients who received primary ankle or ankle-hindfoot arthrodesis (Figures 1a and 1b). It was hypothesized that salvage arthrodesis would perform inferior when compared with primary arthrodesis.

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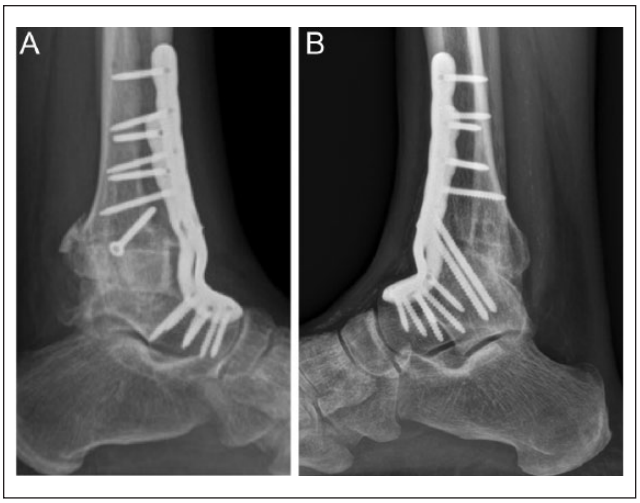

Figure 1. AP and lateral hindfoot views depicting complete arthrodesis in a patient after salvage arthrodesis (A: patient 8-SA in Table 2) and a patient after primary ankle arthrodesis (B: patient 9-PA in Table 2).

Methods

Patients undergoing salvage arthrodesis after failed TAR (group SA) and those undergoing primary ankle arthrodesis (group PA) due to symptomatic end-stage osteoarthritis were included into this retrospective study. Until December 31, 2013, our institutional review board did not require approval for a retrospective review of patient records or images since there was a written agreement between our institution and the review board. However, all patients were informed that their charts and images might have been reviewed for scientific purposes and grants.

We identified 23 patients for group SA who have received salvage arthrodesis operation for failed total ankle replacement in the period between November 2002 and February 2011 at our institution. For group PA 65 matched patients undergoing primary ankle or tibiotalocalcaneal arthrodesis in the same period were identified. All patients were operated on by 3 different surgeons.

To compare outcome and complication rates between the groups, patients from group SA were matched with patients from group PA. Matching was done according to age, etiology of ankle osteoarthritis, nicotine use and arthrodesis type (tibiotalar arthrodesis or tibiotalocalcaneal arthrodesis). The criteria were derived from previously identified risk factors in the literature considering nonunion or impaired clinical outcome after ankle arthrodesis.[21]

Follow-up after salvage arthrodesis averaged 38 months (range 16-92). A successful match according to age, nicotine intake, etiology and arthrodesis type was achieved in 74% (17/23 couples). In 4 pairs only 1 parameter (match criterion: etiology) and in 2 pairs 2 parameters (matching criteria: etiology and nicotine use /etiology and arthrodesis type) were matched which was found when including the 5 TT arthrodesis with already fused subtalar joints to the TT arthrodesis alone. A synopsis of the demographic data and patient characteristics of both groups is given in Table 1. In addition, Table 2 gives detailed information of all patients. In Table 3, group SA information from before implantation of TAR is presented. Among all removed TAR in group SA 16 Agility (DePuy, Warsaw, IN) total ankles, 3 STAR TM Ankle (Waldemar Link, Hamburg, Germany), 2 Hintegra (Smith & Nephew, London, UK), 1 Buechel–Pappas prostheses (Endotech Inc, South Orange, NJ), and 1 SALTO ankle (Tornier S.A.S., Montbonnot Saint Martin, France) were found.

A thorough clinical review was done and included data gathered from charts containing demographics, comorbidities, surgical reports, type of arthrodesis and type of bone graft used during surgery, clinical scoring systems, radiographic assessment (conventional and CT), assessment of the time interval between TAR failure and salvage arthrodesis (in group SA), number of complications, and revision surgeries.

Clinical Assessment

To assess clinical outcome the SF-36 evaluating quality of life[3,12,17,34] and the German version of the Foot Function Index version (FFI-D) were used at the time of final follow-up. The FFI-D is a validated score with subjective evaluation of pain and function.[18,30]

Radiographic Assessment

Standard anteroposterior and lateral radiographs of the ankle under weight-bearing conditions were analyzed. Seventeen cases in group SA and 14 cases in group PA obtained an additional CT scan to assess the union rate and quality of arthrodesis. On conventional radiographs and on CT scans, union was defined as presence of trabecular bridging of at least 50% or more across the arthrodesis zone. Patients without CT scan but who remained pain-free and did not reveal any collapse of the arthrodesis on conventional radiographs 3 months postoperatively were classified as completely united. In a few cases we accepted possible asymptomatic and stable fibrous nonunion.

Surgical Techniques

Group SA. Either an approximately 10 cm longitudinal incision over the anterior aspect of the ankle joint or lateral over the fibula was made (anterior and lateral approach alone used 8 times each, 7 times in combination). In case of a lateral approach the joint needed to be approached through the fibula thus requiring fibular osteotomy. When exploration of TAR showed component loosening, hardware

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Table 1. Demographic Data and Characteristics of Patients in Groups SA and PA.

	Group SA, n = 23	Group PA, n = 23	*P* Value
Mean age (years)	62 (26-79)	59 (38-81)	.507
Extent of fusion			
TT[a]	16	15	—
TTC	7	8	—
Nicotine abuse (yes)	7	6	—
Etiology of OA			—
Primary OA	5	4	—
Posttraumatic OA	15	17	—
Postinfectious OA	1	2	—
Other	2	0	—
BMI (kg/m2)	26 (19-38)	28 (20-37)	.197
Diabetes type 2	3	1	—
Male: female	8 : 15	15 : 8	—
Mean FU (months)	38 (16-92)	56 (23-96)	<.001

Values are given as means including ranges. Statistical differences between the groups are given as *P* values where appropriate. Matched criteria are shaded. BMI, body mass index; FU, follow-up; OA, osteoarthritis; TT, tibiotalar fusion; TTC, tibiotalocalcaneal fusion.
[a]5 patients in group SA already had a subtalar fusion.

removal could smoothly be achieved using an elevator and/or osteotome. This was followed by a meticulous debridement of all fibrous, sclerotic and necrotic tissue. An oscillating saw together with a curette and/or chisel were used to create even surfaces for later interposition of the bone grafts. The surfaces of the tibia, talus and fibula as well were drilled by means of a 2.0mm drill. Depending on the magnitude of bone defect either a tricortical iliac crest autograft alone or a combination of iliac crest autograft and femoral head allograft was used. Cancellous bone graft was harvested from the proximal tibia and/or iliac crest. After thorough irrigation the cancellous bone was inserted circumferentially, surrounding all grafts, creating an envelope of autologous bone between the distal tibia and the talar remnant (Table 2). In case of preoperative symptomatic subtalar joint degeneration, subsequent subtalar joint arthrodesis was added (see Table 2). The surfaces were compressed while carefully checking the hindfoot position. The desired alignment of an arthrodesis was considered neutral in relation to dorsi- and plantarflexion, 5 degrees of hindfoot valgus and an equal or slightly more external rotation than the opposite foot to allow adequate propulsion over the medial ray at final stance. For fixation of the arthrodesis techniques using screws as described by Endres et al,[12,37] blade plates,[18] an intramedullary rod,[37] or anterior double plating (Tibiaxys™ system, Newdeal SA, Lyon, France)[24,31] was used (Table 2). A splint was applied. In 6 cases with septic TAR loosening a 2-step procedure was chosen: First explantation of the infected TAR with insertion of an antibiotic loaded cement spacer was performed. Antibiotic treatment was continued based on microbiological testing for 3 months. After this time antibiotic treatment was discontinued for 1 month. In case of normalized infectious parameters we proceeded with salvage arthrodesis.

Group PA. The same approaches and techniques were used as described in group SA. The ankle was exposed through an anterior approach in 9 cases and a lateral approach in 11 cases; a combined approach was performed in 3 cases. A synopsis of bone graft types, fixation techniques, and number of concomitant subtalar arthrodesis is given in Table 2.

Postoperative Management

The patients were kept in bed for 48 hours with the operated leg elevated. After this time a well-padded removable below-the-knee cast was applied. The patients were kept non-weight-bearing for 8 weeks. At 8 weeks postoperatively the patients were checked clinically and radiographically (conventional radiography and some with CT). If, at this point, radiographic assessment showed sufficient signs of bony consolidation, weight-bearing was progressively increased in a walking cast for a further 4 weeks. Patients were provided with either custom made orthopaedic shoes or stock orthopaedic shoes to improve the gait pattern.

Statistics

The data are presented with means and ranges. Statistical analysis was performed with the PRISM software (PRISM, Graphpad, La Jolla, CA). The data were considered parametric by clinical plausibility, and Student's *t* test was applied to compare the values of the 2 groups. Pearson correlations were used to report the strength of association of

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Table 2. Synopsis of All Matched Patients.

Patient Pairs	Group[a]	Age (Years)	Etiology[b]	Nicotine Abuse	Extent of Fusion[c]	Sex	BMI (kg/m2)	Reason for TP Failure[d]	Bone Graft: Iliac Crest	Bone Graft: Cancellous Bone	Bone Graft: Femoral Head Allograft	Type of Fixation[e]	Surgery Time (Min)	Length of Hospital Stay (Days)	Clinical Follow-up (Months)	Number of Reinterventions	Weeks to Union[f]	Total SF-36 Score (Points)	FFI-D Pain (Total in %)	FFI-D Function (Total in %)
1	SA	67	I°		TTC+	M	24	AL	•	•	•	DP	190	13	45	0	51	72	25	56
	PA	68			TT	F	34	—				S	75	7	30	1	115	80	7	24
2	SA	72	PT		TT	M	28	SL	•	•	•	IN	150	9	25	2	107	41	69	44
	PA	71				M	NA	—		•		S	120	4	59	0	13	76	32	50
3	SA	59	PT		TT	M	30	AL	•	•	•	IN	120	6	24	0	103	53	65	87
	PA	59				M	26	—		•		S	140	10	41	1	A[h]	46	17	74
4	SA	52	PT		TT	M	22	AL	•	•		BP	180	8	46	2	A[h]	32	71	79
	PA	50				M	32	—		•		S	190	7	39	4	A[h]	81	15	14
5	SA	76	PT		TT	F	22	AL	•	•		BP	180	8	27	0	114	33	54	63
	PA	73				F	27	—				S	90	7	94	0	12	54	0	1
6	SA	67	PT		TT	F	33	SL	•	•	•	DP	225	5	24	1	70	44	57	68
	PA	66				M	26	—		•		S	135	7	48	0	13	77	22	36
7	SA	65	PT		TT	F	28	AL	•	•		DP	165	8	16	0	13	55	22	44
	PA	62				F	37	—				S	120	7	39	0	13	90	8	30
8	SA	48	PT		TTC-TT	F	29	AL	•	•	•	DP	180	5	48	0	14	71	49	67
	PA	46				M	30	—				S	120	4	28	3	F[h]	14	81	88
9	SA	54	PT	•	TTC-TT	F	23	AL			•	IN	150	6	23	2	ST[g]	NA	NA	NA
	PA	55				M	26	—				DP	120	5	25	0	14	72	44	47
10	SA	53	PT	•	TT	M	26	AL	•	•		DP	90	3	49	0	14	NA	NA	NA
	PA	45				M	30	—		•		S	130	8	91	0	16	42	88	92
11	SA	75	PT	•	TT	M	29	AL	•	•		DP	160	11	12[g]	0	51	52	82	90
	PA	64				M	29	—				DP	80	5	23	1	56	79	51	38
12	SA	69	PT		TTC-	F	33	AL		•	•	IN	210	17	20	2	58	41	82	71
	PA	46				M	25	—	•			S	135	4	53	1	14	80	21	47
13	SA	71	I°		TTC+	F	24	AL	•			S	80	24	58	1	A[g]	26	74	79
	PA	68				F	30	—		•		S	155	10	87	0	12	71	49	83
14	SA	79	I°		TTC+	F	22	SL	•	NA		IN+S	160	53	41	2	18	NA	NA	NA
	PA	63				M	22	—		•		S	120	8	80	0	A	74	NA	NA
15	SA	58	PT		TTC-TTC+	F	27	AL	•	•		S	120	7	92	3	19	36	72	87
	PA	62				F	29	—		•		S	105	7	78	0	12	77	22	45
16	SA	59	PT		TTC+	F	25	AL	•	•		BP	210	4	48	0	103	79	36	42
	PA	51				M	33	—				IN	240	8	43	2	A[h]	59	49	54
17	SA	71	I°		TT	M	NA	AL	•	•	•	DP	90	4	44	0	26	72	47	70
	PA	74				M	25	—		•		S	120	6	64	0	25	58	22	38

(continued)

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Table 2. (continued)

Patient Pairs	Group[a]	Age (Years)	Etiology[b]	Nicotine Abuse	Extent of Fusion[c]	Sex	BMI (kg/m2)	Reason for TP Failure[d]	Bone Graft: Iliac Crest	Bone Graft: Cancellous Bone	Bone Graft: Femoral Head Allograft	Type of Fixation[e]	Surgery Time (Min)	Length of Hospital Stay (Days)	Clinical Follow-up (Months)	Number of Reinterventions	Weeks to Union[f]	Total SF-36 Score (Points)	FFI-D Pain (Total in %)	FFI-D Function (Total in %)
18	SA	44	PT	•	TT	F	38	AL	•	•	•	IN	195	8	23	15	A[i]	36	51	73
	PA	38				M	22	—				S	60	4	71	3	12	75	51	72
19	SA	26	O	•	TTC-TTC+	F	19	AL	•	•		IN	210	4	37	3	A[h]	80	56	56
	PA	44	Inf			F	32	—		•		S	130	5	54	0	10	94	1	34
20	SA	40	Inf	•	TT	M	21	SL				S	135	8	34	7	A+ST[g]	NA	NA	NA
	PA	41	PT			M	25	—				S	105	4	33	1	19	38	69	78
21	SA	61	O		TTC+	F	26	SL	•	•		S	240	7	26	0	13	NA	NA	NA
	PA	53	Inf			M	31	—		•		S	120	13	86	1	A[g]	70	60	51
22	SA	75	1°		TTC+	F	30	SL	•	•		DP	165	9	44	4	51	33	63	89
	PA	79	PT			F	20	—				S	150	7	59	1	A+ST[g]	84	10	18
23	SA	77	PT	•	TTC+	F	26	AL	•	•		S	180	12	62	2	18	7	60	98
	PA	81				F	27	—	•			BP	150	10	60	0	17	34	19	45

Matched patient pairs are arranged together. Matching criteria are highlighted in light gray; patients with nonunion after index arthrodesis are highlighted in dark gray.

[a]Groups: SA, salvage arthrodesis; PA, primary arthrodesis.

[b]Etiology: 1°, primary osteoarthritis; PT, posttraumatic osteoarthritis; Inf, postinfectious osteoarthritis; O, other causes of osteoarthritis.

[c]Extent of fusion: TT, tibiotalar fusion; TTC+, 1-stage tibiotalocalcaneal fusion; TTC-, ankle fusion on previously fused subtalar joint.

[d]Reason of failure of ankle arthroplasty: AL, aseptic loosening; SL, septic loosening.

[e]Type of fixation technique: DP, anterior double plating; S, screw fixation; IN, retrograde intramedullary nailing; BP, blade plate fixation.

[f]Nonunions: A, at the ankle; ST, at the subtalar joint; F, fibulotalar. Evolution after revision: [i]stiff fibrous nonunion; [g]bony fusion; [h]lower leg amputation. This patient past away in the mean time. The last clinical outcome 2 years postoperatively was good according to the chart but we have only scores in the 1-year follow-up.

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Table 3. Summary of the Patients in Group SA With the Information Before Achieving a TAR.

Group SA	Previous Operations Before TAR	TAR Failure Reason	Time in Months From TAR to Salvage Arthrodesis
Patient 1	ORIF of a trimalleolar fracture	Aseptic loosening	13
Patient 2	ORIF and hardware removal of a trimalleolar fracture	Aseptic loosening	26
Patient 3	ORIF after initial external fixator of a trimalleolar fracture	Septic loosening	6
Patient 4	None	Septic loosening	34
Patient 5	None	Aseptic loosening	53
Patient 6	None	Septic loosening	69
Patient 7	None	Septic loosening	15
Patient 8	1. ORIF femur and tibia and hardware removal, 2. talocalcaneal and calcaneocuboideal arthrodesis	Aseptic loosening	8
Patient 9	Triple arthrodesis	Aseptic loosening	60
Patient 10	None	Aseptic loosening	78
Patient 11	ORIF and revision operation by nonunion of a trimalleolar fracture	Aseptic loosening	42
Patient 12	Multiple operations and revisions of a osteochondrosis dissecans in the talus	Aseptic loosening	51
Patient 13	ORIF and metal removal of a bimalleolar fracture, arthroscopic ankle adhesiolysis and peroneal tendon revision talus cyst augmentation	Septic loosening	58
Patient 14	ORIF and hardware removal of a trimalleolar fracture	Aseptic loosening	41
Patient 15	ORIF and re-ORIF of a trimalleolar fracture	Aseptic loosening	74
Patient 16	ORIF and hardware removal of a tibia fracture, tibia valgisation osteotomy, limited double arthrodesis	Aseptic loosening	131
Patient 17	ORIF and hardware removal of a trimalleolar fracture, arthroscopic adhesiolysis, and removal of osteophytes	Aseptic loosening	95
Patient 18	ORIF tibia and fibula and hardware removal of a multifragment lower leg fracture	Aseptic loosening	19
Patient 19	Ankle arthroscopy and open synovectomy, ankle arthrodesis, subtalar arthrodesis, wound revision, closing wedge extending osteotomy of the metatarsal I	Aseptic loosening	92
Patient 20	None	Aseptic loosening	130
Patient 21	None	Septic loosening	17
Patient 22	None	Aseptic loosening	76
Patient 23	Talonavicular arthrodesis	Aseptic loosening	92
Mean			56
Max			131
Min			6

investigated factors, such as the association of radiologic measures to the clinical scores. Significance was defined with a P value < .05, according to common consensus.

Results

Clinical Outcomes

The subjective SF-36 and FFI-D scores were completed by all patients of group PA and in 18 of group SA (6 patients did not complete the entire sheets leaving missing data).

Patients in group SA showed significantly worse outcomes regarding the total SF-36 score/SF- 36 physical function and the FFI-D subscores for pain and function as well. Patients of group PA had less pain and better function as well as improved life quality when compared with patients of group SA. This is also true if only patients in whom primary arthrodesis without further revision operations was achieved are considered. Furthermore, when excluding the 6 patients in group SA with septic loosening the group showed significantly worse results when compared with primary arthrodesis (Table 4).

Operation time was significantly longer in group SA averaging 167 minutes (range 80 to 240) when compared with group PA (mean operation time: 127 minutes; range 80

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Table 4. Summary of Mean Scores With Ranges for the Total SF-36/SF-36 Physical Function and FFI-D Pain and Function Reached by the Patients in Groups SA and PA.

	Group SA	Group PA	*P* Value
	All Patients		
	n = 18 (23)	n = 23 (23)[a]	
SF-36 total	48 (7-80)	66 (14-94)	.006
SF-36 physical function	42 (0-100)	63 (5-100)	.021
FFI-D pain (%)	57 (22-82)	34 (0-88)	.002
FFI-D function (%)	71 (44-98)	48 (1-92)	.002
	Matched Pairs With Completed Score Sheets		
	n = 18 (18)	n = 18 (18)[a]	
SF-36 total	48 (7-80)	68 (14-94)	.005
SF-36 physical function	42 (0-100)	65 (5-95)	.013
FFI-D pain (%)	57 (22-82)	27 (0-81)	<.001
FFI-D function (%)	70 (44-98)	44 (1-88)	<.001
	Nonunions		
	n = 4(6)	n = 6-7 (7)[a]	
SF-36 total	43 (26-80)	61 (14-84)	ns (.3)[b]
SF-36 physical function	51 (30-100)	62 (5-100)	ns (.6)
FFI-D pain (%)	63 (51-74)	38 (10-81)	ns (.1)
FFI-D function (%)	72 (56-79)	50 (14-88)	ns (.2)
	Successful Unions		
	n = 14 (17)	n = 16 (16)	
SF-36 total	49 (7-79)	69 (34-94)	.009
SF-36 physical function	40 (0-70)	63 (20-95)	.016
FFI-D pain (%)	56 (22-82)	32 (0-88)	.006
FFI-D function (%)	70 (44-98)	48 (1-92)	.007
	Excluding the 6 Septic Patients in Group SA		
	n = 15 (17)	n = 23 (23)	
SF-36 total	49 (7-80)	66 (14-94)	.012
SF-36 physical function	40 (0-100)	63 (5-100)	.017
FFI-D pain (%)	57 (22-82)	34 (0-88)	.002
FFI-D function (%)	71 (44-98)	48 (1-92)	.002

For the total SF-36 and the physical function subscore, a maximum score of 100 points indicates best and 0 points worst possible quality of life. For the FFI-D percentage score 0% indicates least pain and best function. The results are given for all patients with completed score sheets, for those matched couples in which for both patients completed sheets are available and for the subgroups of patients with successful bony arthrodesis or nonunion after first attempt to arthrodesis. Furthermore, the results are given for the patients when excluding the patients who have had a septic loosening in group SA.
[a]1 patient completed the SF-36 score sheets only.
[b]ns, not significant.

to 240; $P = .003$). The duration of hospitalization did not significantly differ between the groups, with 11 days (range 3 to 53) for group SA and 7 days (range 4 to 13) for group PA ($P = .116$). One patient of group SA showed an excessively prolonged hospitalization of 53 days due to wound complications that were treated with antibiotics and multiple soft-tissue debridements.

Nonunion

Interestingly, although massive graft interpositions were needed in group SA the number of nonunions was found to be similar when compared with group PA (6 vs 7 nonunions, respectively; see Tables 2 and 3). All patients with a completely fused arthrodesis (as confirmed clinically and radiographically) were compared regarding their clinical outcomes and showed statistically significant inferior outcomes in group SA (Table 4).

Complications and Revision Operations

The average number of additional revision surgeries for each group was 1.5 per patient in group SA (35 reinterventions total) and 0.5 in group PA (12 interventions total). Simple hardware removal has not been included in this calculation (11 in group SA, 7 in group PA). However, the high number of subsequent interventions in the SA group was partially due to 2 patients who had 22 revisions—mainly wound debridements with closed suction therapy but also rearthrodesis. Both patients ended catastrophically, 1 with

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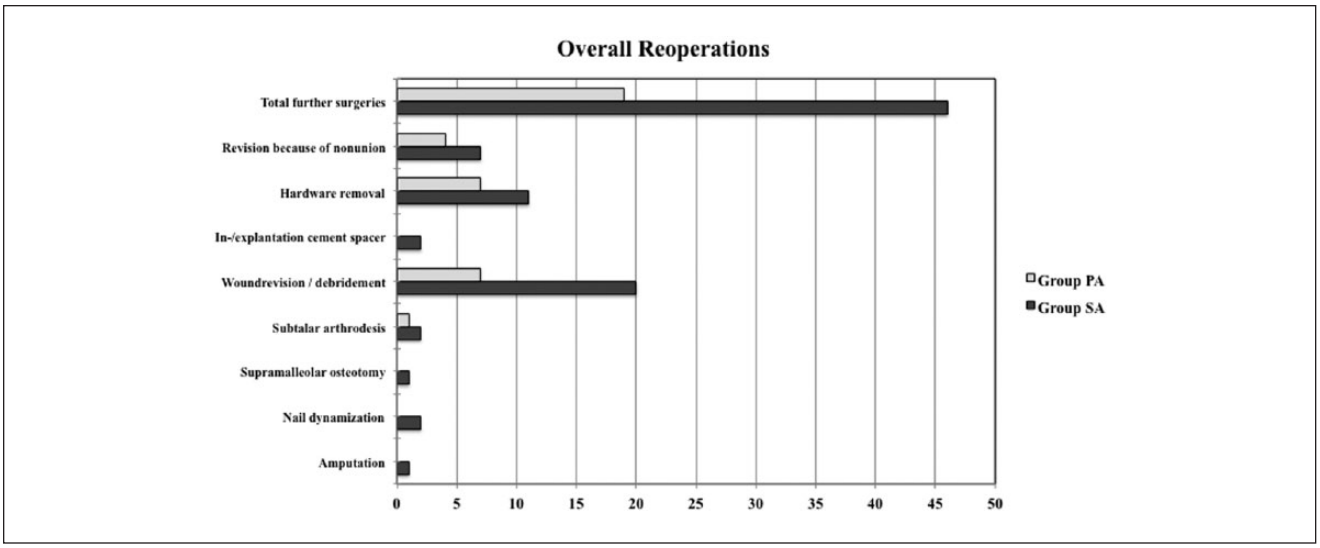

Figure 2. Reinterventions: Overview of all subsequent operations. Group PA had an overall reoperation rate of 0.8 per patient (19 reinterventions total); patients in group SA experienced a reoperation rate of 2 per patient (46 reinterventions total). If hardware removals were excluded, reoperation rates dropped to 0.5 for group PA and 1.5 for group SA.

lower leg amputation and the other with a stiff, painful nonunion. When omitting those 2 patients in the statistical analysis, the revision operation rate dropped from 1.5 per patient to 1.0 per patient in group SA. The overall reoperations are reported in Figure 2.

Discussion

The current study demonstrated inferior clinical outcomes in patients who undergo salvage arthrodesis after failed TAR when compared with patients who undergo primary arthrodesis due to symptomatic end-stage arthritis. Therefore, our initial hypothesis was confirmed.

TAR and ankle arthrodesis show similar revision rates (1 year: 9% vs 5-7%/5 years: 23% vs 11%), clinical outcomes (good to excellent outcomes: 78% TAR and 73% ankle arthrodesis), and low rates of secondary subtalar arthrodesis (1% and 2.3%, respectively).[17,34] However, longevity of TAR remains limited, with 5-year survival rates of 78%-89% and 10-year rates between 62% and 76%.[13,19,32]

When a TAR fails, revision surgery may be needed. While there are still only few implants on the market offering revision components for TAR exchange, removal of TAR and conversion into an arthrodesis has found widespread use in clinical practice. However, salvage arthrodesis after failed total ankle replacement is a difficult procedure. First, the amount of osseous defect after implant removal requires the use of allogenic and/or autologous bone graft to fill the void. Second, fixation of the arthrodesis zone needs to be stable enough to allow osseous integration and healing. Third, soft-tissue handling is often critical as there have been prior surgeries performed on the ankle joint. Therefore, salvage arthrodesis after failed TAR could potentially perform worse than primary ankle arthrodesis. In this study, patients who underwent salvage arthrodesis for failed TAR demonstrated a significantly worse quality of life, higher levels of pain and impaired function. A fact that cannot be neglected when informing the patient about TAR and possible conversion into an arthrodesis.

It is difficult to properly and completely understand the differences in clinical outcome. However, patients who undergo salvage arthrodesis after TAR usually have had several previous surgeries. In addition, large bone grafts cause inflammatory responses with potentially subsequent painful sensation that may partially explain the findings.[1,5,16,17,19,25,32]

A relevant and potentially debilitating complication after arthrodesis is nonunion. The nonunion rate of the entire study population of the matched control group (n = 65) was 20% (13 patients). Group SA showed a nonunion rate of 26% (6 out 23 patients) versus 30% (7 out of 23 patients) in group PA. Thus, the nonunion rate was comparable between both groups although in group SA large bone grafts were used to bridge the defect zone. Those nonunion rates are comparable to data previously published in the literature with values ranging from 0% up to 39%.[4,6,7,10,14,15,19,24,26,28,33,36,38,40] The high nonunion rate in group PA could partially be explained by chance and the fact that the population was a matched control group. As such the nonunion rate does not reflect the true nonunion rate in the entire arthrodesis population of our hospital. Besides this, in group PA, 4 of the 7 nonunions occurred in patients who underwent a TTC fusion. The current literature of small series report a union rate of 58 to 93 % after TTC fusion which confirms this large variability

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Table 5. Summary of All Relevant Literature Regarding Salvage Arthrodesis After Failed Total Ankle Replacement.

Author	N	Age	Diagnosis	t → Fusion	F-Up	Type of TAR	Fusion (%)	Technique	Graft	Score	Comments
Carlsson et al	21	59 (25-76)	16 RA 3 OA 2 SD	40 (6-184)		8 Bath & Wessex 4 LCS New Jersey 3 ICLH 2 STAR 2 St. Georg	62	16x external fixator 2× casting 2× screw fixation 1× IM rod	5× fibula + cancellous bone 4× iliac crest (cancellous bone) 5× iliac crest 3× allograft-cancellous bone 2× allograft	NA	15 patients good to excellent
Zwipp and Grass	4	45 (39-55)	4 OA	46 (18-120)	26 (18-48)	2 STAR 2 Link	100	3× cancellous screws (TT) 1× anterior double plating (3.5 LCDCP)	Iliac crest	NA	All patients pain free
Hopgood et al	23	62 (30-76)	12 OA 11 RA		29 (12-60)	15 STAR 6 Buechel–Pappas 2 Andere	74	13× cancellous screws (8 TT/5 TTC) 10× IM rod (TTC)	6× iliac crest 8× synthetic bone 9× direct fusion	AOFAS 61 (35-80)	RA risk factor for nonuion
Culpan et al	16	54 (24-78)	13 OA 2 RA 1 PVNS	41 (10-110)	44 (6-156)	8 Salto 3 Buechel–Pappas 2 STAR 1 LCS New Jersey 1 Ramses 1 custom made	94	16× cancellous screws	16× iliac crest	AOFAS 70 (41-87)	
Schill	15	56 (46-76)	10 RA 5 OA	66 (20-120)	23 (7-36)	8 STAR 6 Thompson–Richards 1 Salto	93	15× IM rod (TTC)	15× iliac crest 15× fibular grafts	AOFAS 58 (35-81)	Lateral approach in all cases
Thomason and Eyres	3	66 (46-86)	3 OA	152 (108-228)	32 (13-50)	3 Buechel–Pappas	100	3× IM rod (TTC)	3× femoral allograft	NA	
Doets and Zürcher	18	55 (27-76)	15 RA 3 OA	48 (2-156)	88 (36-144)	11 Buechel–Pappas 6 LCS New Jersey 1 CCI	61	6× blade plate 6× IM rod 4× screws 1× K-wires	15× iliac crest 3× cancellous bone	AOFAS 62 (38-89) FFI (70 (62-78)	RA risk factor for nonunion
Henricson et al	13	KA	7 OA 6 RA	78 (24-192)	17 (7-41)	9 STAR 2 AES 1 Mobility 1 Buechel–Pappas	100	13× IM rod (TTC)	13× metal cage + 9× allograft 4× cancellous bone	NA	
Berkowitz et al	24	62 (40-82)	19 OA 3 RA 2 HA	52 (7-192)	44 (8-106)	18 Agility 7 STAR 2 Buechel–Pappas	79	6× IM rod (TTC) 3× IM rod and plate 3× anterior AO plate 3× screws	8× cancellous allograft 7× PRP 3× femoral allograft 3× Iliac crest cancellous bone 3× iliac crest allograft 9× other	AOFAS 69 (8-106)	TTC tends to nonunion

HA, hemophilic arthropathy; OA, osteoarthritis (including primary and posttraumatic); PVNS, pigmented villonodular synovitis; RA, rheumatoid arthritis; t → fusion, time until fusion; TTC, tibiotalocalcaneal arthrodesis.

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and might depend on several factors like comorbidities, etiology and defect size. Further it is crucial whether stiff nonunions have been counted in the union group or in the nonunion group.[2,7,22,33] None of the patients with nonunions in group PA had diabetes. One patient in the SA nonunion group had diabetes. Nevertheless, the clinical results for completely fused hindfoot arthrodeses has been found to be superior in group PA (Table 4). In addition, a separate analysis excluded those patients who had septic loosening in group SA and revealed no major changes with persistent inferior results. Due to the small number of patients with septic loosening no clear conclusion can be drawn regarding correlation between previous infection and outcome.

One limitation of the study is the rather small study populations. To obtain valuable and reliable data, matching was performed to get as homogenous and comparable groups as possible. Further there was some concern regarding the matching criteria. Although, there may be other influencing factors regarding outcome, for example, BMI or other comorbidities, we are confident that we chose the most critical and matchable factors considering arthrodesis based on the current literature. Another important factor was diabetes mellitus, although in these 2 groups there were only 3 patients in group SA and 1 patient in group PA with diabetes. Therefore this factor was not relevant in our study. Besides this, the current study represents one of the largest patient series considering salvage arthrodesis after failed TAR. Proper outcome data could be obtained only at final follow-up. However, we were mainly interested in final clinical outcome. Also, the inclusion of patients with tibiotalocalcaneal arthrodesis could be a possible weakness because they do worse regarding overall function. In addition, patients after tibiotalocalcaneal fusion have different problems when compared with primary arthrodesis. The present study showed a wide spectrum of complications and problems, which cannot be attributed to tibiotalocalcaneal arthrodesis alone.

A strength of the study was the use of validated outcome scoring instruments. To our knowledge, this has not yet been done by previous authors[2,6,7,10,19,21,33,37,40] (Table 5). As such the current data are seen to be reliable enough to provide the readers with important data regarding the outcome of salvage and primary arthrodesis of the ankle.

Conclusions

Patients who undergo salvage arthrodesis perform worse when compared with patients who get primary arthrodesis with greater morbidity and impaired life-quality. When selecting patients for TAR, caution is advised when explaining conversion of failed TAR into arthrodesis to the patient. It will most likely not be as successful as primary arthrodesis. Therefore, salvage measures after failed TAR need to be discussed and weighted according to the patient's needs.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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